International Journal of Business Management & Research (IJBMR)
ISSN(P): 2249-6920; ISSN(E): 2249-8036
Vol. 6, Issue 2, Apr 2016, 85-96

PREFERENCES FOR DOMESTIC COOKING FUELS AMONG RURAL HOUSEHOLDS IN KARNATAKA

RANGANATH, G.[1], R. VENKATRAM[2] & K. MAHENDRAN[3]

[1]*Research Scholar, Student, Department of Arm, Tnau, Coimbatore, Tamil Nadu, India*

[2]*Professor, Department of Arm, Tnau, Coimbatore, Tamil Nadu, India*

[3]*Professor and Head, Department of Arm, Tnau, Coimbatore, Tamil Nadu, India*

ABSTRACT

The choice of domestic fuel is a matter of great concern for households and policymakers in India. This paper investigates the switching preference of the rural households from traditional fuel wood towards cleaner fuels like Biogas, LPG and Kerosene. The study is based on a survey among 60 households residing in two villages namely, Muthakadahalli and Shettyhalli of Chickballapur district, Karnataka. The cost-benefit analysis of the Biogas units in the study area yielded appreciable NPV, B-C ratio and IRR. Inspite of this there has not been any large scale adoption of the household type Biogas units, unless there is some intervention from government departments and NGO's operating in the area. Therefore Conjoint analysis was used in order to analyze this dynamic behaviour of the rural households in switching their domestic fuel preferences. Eleven attributes namely: Durability, Reliability, Sophistication, Space, Ruggedness, Cost, Interest, Subsidy, Services, Distribution and Safety were selected along with their three respective levels; LPG, Biogas and Kerosene. Using the conjoint function utility (part-worth) scores were generated which indicated the preference of fuels with respect to each attribute. Here LPG was the clear winner among other fuels as it received highest positive utility score for majority of the attributes. However, given the increasing subsidy burden, import bills, energy security concerns and long term sustainability, universal LPG coverage in the country may prove to be a sub-optimal solution to meet clean cooking energy needs. Therefore a comparative assessment of domestic fuels available in the study area comprising of Biogas, LPG and Kerosene was carried out. Even though Biogas was found to be the most capital intensive solution during the installation period, continuous fuel supply was assured based on the operational availability of the plant. On the resilience of technology front Biogas plants and Kerosene stoves fared the worst indicating that there was still some way to go before end-users viewed these solutions on par with LPG.

KEYWORDS: Domestic Fuels, Switching Preference, Rural Households, Conjoint Analysis, Comparative Assessment

Received: Mar 20, 2016**; Accepted:** Apr 04, 2016**; Published:** Apr 09, 2016**; Paper Id.:** IJBMRAPR201609

Original Article

INTRODUCTION

An economy's development would be reflected in its consumption of energy. Especially in case of developing countries, it will be accompanied by a shift within country households toward increasing use of modern fuels. Decreasing reliance on biomass is another factor that reflects progress even in the absence of policies explicitly aimed at achieving this outcome. The type of fuels used by a rural household is determined mainly by its socio economic condition. In many developing countries, biomass fuels namely animal dung, crop residues and firewood are used mostly by very poor people in rural areas (Kanagawa and Nakata, 2008). The gathering of firewood and other biomass fuel is a strenuous and time consuming task for rural poor. The same time can be devoted towards other income generating activities if they could arrange some alternate fuel which is preferably less

time consuming and has a higher operational efficiency. On the other hand firewood collection and consumption are intricately linked to the degradation of natural resource especially the forest, leading to a situation of firewood scarcity. Therefore it will lead to a number of other adverse consequences like forest degradation, including loss of biodiversity, release of carbon dioxide into atmosphere and soil erosion (Heltberg *et al*., 2000). Similarly, burning biomass in open-fire stoves and often with little ventilation, emits smoke containing large quantities of harmful pollutants, with serious health consequences for those exposed, particularly women involved in cooking and young children spending time around their mothers (Kumar *et al*., 2007). Several recent studies have shown strong associations between biomass fuel combustion and increased incidence of chronic bronchitis in women and acute respiratory infections in children.

Historically in India, biomass fuels constitute the predominant sources of energy, especially for cooking. The most important biomass in rural India are firewood, collected from forests, common lands, roadsides, and private fields; crops residues from farm; and dung, gathered from domestic animals. Firewood is used in almost all rural households. Though these traditional fuels are predominant in rural areas, but the pattern of their use is changing (Viswanathan *et al*., 2005). A shift in demand for kerosene, biogas and LPG as domestic cooking fuels is observed among the better income groups in rural areas. Kerosene and electricity are used as a fuel for domestic lighting (Chaurey and Kandpal, 2009). However, this switch is negligible as compared to the use of traditional fuels, which is predominant across all income groups.

Over the years there has been a phenomenal growth in the Indian population which has brought in its wake a surge in domestic fuel demand. This is particularly important in a developing country like India where domestic fuel consumption in rural areas forms a significant part of total energy demand as the majority of population resides in rural and semi urban areas. From an environmental point of view there are two areas of concern here. On the one hand, there is usage of traditional fuels such as wood, dung cakes and coal that have local environmental effects such as smoke, smog and indoor air pollution. On the other hand, there is usage of modern, commercialized fuels such as electricity, Liquified Petroleum Gas (LPG), Kerosene, Piped Natural Gas (PNG) which does not cause significant smoke but may have global environmental impact through emission of greenhouse gases. There are thus several reasons why the choice of domestic fuel in rural areas of the developing world is important to study, ranging from the importance it has on individual welfare to its implications on global warming. India is an ideal place to study this, representing a billion people, a sixth of the world population, and a swift transition of domestic fuel use from wood-based fuels to petroleum based and other cleaner fuels.

In the past, there have been various attempts by the government to promote cleaner fuels. The standard approach was to change the relative fuel prices by providing subsidies. The approach has not been very successful in bringing energy transitions, especially in the lower income groups. The poor delivery infrastructure; high cost of connection and refilling; and availability of competing fuel choices in the form of fuel wood and other biomass fuels at zero cost remain as obstacles to quick diffusion of modern fuels in the rural household (The Energy and Resources Institute, 2004).

India has subsidized LPG for over three decades in order to facilitate a transition from unclean traditional cooking fuels to modern and cleaner forms of cooking energy. Although the complete transition is only limited to 20% of the population (Jain, Agrawal and Ganesan, 2014), the rising subsidy outlay on domestic LPG and excessive import dependence pose grand challenges in meeting the demand. India’s reliance on this imported fossil fuel was as high as ~89 per cent for the year 2012-13 (CSO, 2013). Such sustained and high import dependence has two negative implications; the

rising current account deficit and the increasing concerns about energy security associated with the provision of an essential service such as clean cooking energy for the massive population.

Given the increasing subsidy burden, import bills, energy security concerns and long term sustainability, universal LPG coverage in the country may prove to be a sub-optimal solution to meet clean cooking energy needs. The lack of diversification and a near-total reliance on LPG would also have repercussions for energy security from the point of view of locking into a single technology. Moreover, the challenges and resources associated with transportation and distribution of LPG, especially to the far flung remote areas with poor and limited accessibility, pose barriers to universal LPG adoption. Thus, in order to provide clean cooking energy to all, while LPG is being promoted and adopted, it is necessary to look at the alternative cooking energy options and evaluate their suitability to provide clean, affordable and sustainable cooking energy under different contexts, while recognizing the difference in the level of service provided by each. Such a process would have to consider, *inter alia*, the economics and financial viability, the impact on energy security, the reliability and usability of each option. Only such an exhaustive evaluation can inform policymakers of the options, which can complement or effectively displace LPG in providing universal coverage of clean cooking energy for all (Jain, Choudhury and Ganesan, 2015).

This study attempts to conduct such an evaluation of the alternative options and present a comparative assessment across multiple criteria. The choice of domestic fuel is a matter of great concern for households and policy makers in India. Kerosene, biogas and Liquid Petroleum Gas (LPG) are the 3 domestic fuels used in the study area for which the preference study has been made. Fuel wood which was used to be the predominant domestic fuel source has been significantly replaced by the aforesaid fuels in the study area. But it is still used for some limited domestic operations such as water heating in the study area.

Therefore the main objective of the study is to analyze the switching preferences of the rural households with respect to fuel usage for cooking purpose and to compare the utilities of the domestic fuels available in the study area.

MATERIALS AND METHODS

- **Study Area and Data**

The study has been conducted in the Chickballapur district of Karnataka state. Muthakadahalli and Shettyhalli are the two villages from which the primary data has been sourced. The sampling method used for this study is purposive sampling. Thirty households who have installed $2m^3$ household type biogas plants were surveyed for the cost-benefit analysis. Further Sixty respondents were surveyed for the analysis of switching preferences of domestic cooking fuels in the study area. Several research papers, reports and other literature were reviewed in order to elucidate sustainable strategies and practices of renewable energy based fuels in the long run which forms the secondary data used for the study.

A standard household questionnaire was used for the survey conducted in October 2015. The questionnaire at household level covered demographic information, income sources (on and off-farm), resource and asset endowment, land cultivation, agricultural input use and crop yields, food availability and access, food security status, labour and energy management. Apart from the households, administrative officials (Panchayat Development Officer) and Non-Governmental Organizations (NGO) were also the key informants for the study.

- **Cost-Benefit Analysis**

The internal rate of return (IRR), net present value (NPV) and Benefit-Cost ratio (B-C) were used to assess the

competitiveness of biogas plants in the study area (Isabel Barfuss et.al. 2012).

NPV and IRR are given by the following:

$$\mathrm{NPV} = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t},$$

IRR is the discount rate ‘i’ such that

$$\sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t} = 0$$

Where, B_t is the benefit in each year, C_t are the costs in each year, i is the interest (discount) rate, t are numbers from 1, 2, 3, n where n is the number of years (life of biogas plant). A discount rate of 12 per cent was chosen for this study on the basis of the long run rate of return on capital.

Small-scale biogas plants are often justified on the basis of the private cost and benefit accruing to the individual household (Srinivasan, 2008). A financial cost-benefit analysis takes account only of the costs and benefits of the project to the private farm - its effect on revenues and costs and ultimately attention to getting maximum profit. Financial estimation of a biogas plant includes four assumptions: with subsidy (base assumption), without subsidy, health facility issues, and income generating issues (Kabir and Palash, 2012). In this study without subsidy means a situation where no outreach incentive is incorporated into the calculation of a biogas plant, rather, the normal manner a human uses for incentives for adopting new technology. Without subsidy estimation of a biogas plant gives the real lesson too society for the adoption of biogas. Hence, to know the actual cost to be incurred for installation of a biogas plant, any subsidy money was subtracted from the calculated cost of each capacity and each model.

Expanding new technology needs new initiatives to encourage people to adopt, like subsidy, a very strong instrument urging people to make the decision in favor of new technology adoption. The use of biogas has contributed to notable benefits regarding health, socio-economic status, women’s and children’s work load, plus agricultural and environmental issues. Households have stated significant benefits resulting from reduced air pollution and associated eye and respiratory diseases. The atmosphere has become cleaner, a positive impact on the health of households (IDE, 2011). Thus, biogas users pay less money for medical purposes due to improved health.

- **Cost Estimation of Domestic Biogas Plant**

There were mainly two types of costs incurred, namely,

- Capital and installation costs
- Operating and maintenance cost.

Costs incurred in fixing the 2m³ digester in the respondent’s premises formed the capital and installation cost. It takes into account all the costs of raw materials like bricks, sand, cement, PVC pipes, gas holder/drum/digester, iron bars, technical/masonry services, stove etc. and other related costs. The cost of fresh dung input for the family-sized biogas plants was considered to be the main operational cost. In addition to it, labour cost was also considered as the households regularly devoted two to three hours labour towards biogas generating activity. Annual operation and maintenance (O&M)

costs of biogas plants were related to repairing, maintenance and replacement of spares.

- **Benefit Estimation of Domestic Biogas Plants**

Quantification of the benefits of a biogas system is a crucial step in the economic viability evaluation of biogas activities. The benefits accruing from establishing and running a biogas digester fall into two basic categories: monetary and environmental. The monetary benefits are the saved costs on fuel substituted by biogas and on fertilizer costs substituted by digester slurry (Purohit and Kandpal, 2007; Biswas and Lucas, 1996). Here the saved costs on fuel are the costs of LPG, kerosene and fuel wood. It is essential to find an indirect method to evaluate the benefits, and the most logical method is to place market values in term of alternative fuels for a given end use (Singh and Sooch, 2004). In this study, the total benefits from slurry used is accounted by money saved per year by reduction in application of chemical fertilizers were used for calculation.

- **Conjoint Analysis**

Conjoint uses the **full-profile** (also known as full-concept) **approach**, where respondents rank, order, or score a set of profiles, or cards, according to preference. Each profile describes a complete product or service and consists of a different combination of factor levels for all factors (attributes) of interest. Using conjoint analysis we can determine both the relative importance of each attribute as well as which levels of each attribute are most preferred. If the most preferable product is not feasible for some reason, such as cost, we would know the next most preferred alternative. If we have other information on the respondents, such as background demographics, we might be able to identify market segments for which distinct products can be packaged. For example, the business traveler and the student traveler might have different preferences that could be met by distinct product offerings.

Therefore similar methodology has been applied to analyze the switching preference of domestic cooking fuels among rural households. The analysis has been done using **SPSS16** software package.

RESULTS

- **Cost-Benefit Analysis of Household Type Biogas Plants (2m^3)**

In the study area there were many household type biogas plants installed and were found to be functioning well over the years. Therefore in order to analyze the economic viability of the biogas plants, three economic decision criterion were used, namely, Net Present Value (NPV), Benefit-Cost Ratio (B-C ratio) and Internal Rate of Return (IRR). A useful economic life of a fixed-dome digester of 15 years was assumed in this study as has been in other similar studies (Kabir and Palash, 2012).

Cost-Benefit Analysis with Subsidy

The average capital and installation cost, operating and maintenance costs have been calculated for a period of fifteen years. The average capital and installation cost was found to be Rs. 11,498 and the average operating and maintenance cost was Rs. 4,950 per year. A discount rate of 12 per cent was applied in order to arrive at discounted costs and benefits which paved the way for the calculation of NPV, B-C ratio and IRR.

Table 1. Indicates the NPV, B-C ratio and IRR of the household type 2m^3 biogas plants calculated for the period of 15 years. NPV is found to be positive i.e. 38127 and B-C ratio was greater than one i.e. 1.96. IRR is greater than the opportunity cost of capital (12 per cent) i.e. 39 per cent. Therefore the biogas project with subsidy is a financially viable

project.

Table 1: Discounted Measures of Project Worth for Household Type Biogas Plants with Subsidy

Discounted Measures	Calculated Value with Subsidy
NPV (Rs.)	38127
BCR	1.96
IRR (Per cent)	39

Cost-Benefit Analysis without Subsidy

The average capital and installation cost, operating and maintenance costs have been calculated for a period of fifteen years. The average capital and installation cost was found to be Rs. 21,698 and the average operating and maintenance cost was Rs. 4,950 per year. A discount rate of 12 per cent is applied in order to arrive at discounted costs and benefits which paved the way for the calculation of NPV, B-C ratio and IRR.

Table 2. Gives the NPV, B-C ratio and IRR of the household type 2m³ biogas plants calculated for the period of 15 years without subsidy. NPV was found to be positive i.e. 25602 and B-C ratio is greater than one i.e. 1.52. IRR is greater than the opportunity cost of capital (12 per cent) i.e. 26 per cent. Therefore the biogas project without subsidy was also found to be a financially viable project.

Table 2: Discounted Measures of Project worth for Household Type Biogas Plants without Subsidy

Discounted Measures	Calculated Value without Subsidy
NPV (Rs.)	25602
BCR	1.5
IRR (Per cent)	26

Household biogas units have got an appreciable IRR when calculated with subsidy and without subsidy scenarios. In addition to it, there was a lower cost of production and subsidy backing from various government as well as non-governmental organizations. In spite of these positive attributes, the demand for household biogas units was not up to the mark in the study area when compared to that of LPG. The demand was picking up in the areas wherein several NGO's and government departments are actively backing and promoting renewable energy. Two NGO's namely BCS-FCF (Bagepalli Coolie Sangha, India-Fair Climate Fund, Netherlands) and SKG Sangha (2007 Ashden award winner) are actively involved in promoting and disseminating household type biogas technologies as a part of Clean Development Mechanism (CDM) project intended towards reducing the carbon emissions. Therefore the demand for biogas plants was a sort of induced demand and not a desired or effective demand. Whereas the survey suggested that there was an inherent demand among the households to opt for LPG connections in the study area even though it was costlier compared to biogas, especially in terms of operational cost. However this dynamic behaviour of the rural households in switching their domestic fuel preferences forms the next part of analysis.

Conjoint Analysis for analyzing the switching preferences for domestic cooking fuels among the households in the Study area

Eleven factors or attributes have been identified for the analysis and their respective factor levels are specified. Each factor has three factor levels, namely, LPG, Biogas and Kerosene. These three fuels were selected for the analysis due to its extensive usage in variable proportions among the households selected for the study. The selected attributes are;

- **Durability**: It refers to the life-cycle of the cooking device. Longer durability indicates longer life-cycle and vice versa.
- **Reliability**: It refers to the assurance of fuel supply for cooking.
- **Sophistication**: It refers to the advanced technology used in cooking.
- **Space**: It refers to the space needs of the cooking device.
- **Ruggedness**: It refers to physical and mental strain resulting from the cooking process.
- **Cost**: It refers to installation and operational costs.
- **Interest**: It refers to the periodical interest payment on account of the loan taken for the purchase or installation of the cooking device.
- **Subsidy**: It refers to the subsidy component provided by the government as well as non government organizations for the installation and operation of a particular cooking device.
- **Services**: It refers to the after sales services available to the cooking device in and around the vicinity of the user.
- **Distribution**: It refers to the distribution channel or ease of procurement of a particular fuel or cooking device.
- **Safety**: It refers to the safety of the users while cooking on a particular cooking device.

After defining the attributes and attribute levels, a fractionated factorial experimental design was generated using Conjoint Design SPSS 16 software. The resulting set, called an orthogonal array, is designed to capture the main effects for each factor level. The Generate Orthogonal Design procedure is used to generate an orthogonal array and is typically the starting point of a conjoint analysis. Each set of factor levels in an orthogonal design represents a different version of the product under study and is presented to the respondents in the form of an individual product profile or conjoint cards. This helped the respondent to focus on only the one product currently under evaluation. The conjoint cards were given to the respondents and were asked to rank the cards in terms of decreasing order. After the preference data was collected from all the respondents, the analysis resulted in the utility (part worth) scores for each factor and factor levels.

Table 3. Indicates the utility estimates for all the factor levels coming under their respective factors. Higher utility values indicated greater preference. LPG score was higher in terms of Durability, Reliability, Sophistication, Space, Ruggedness and Distribution. Whereas Biogas was preferred in terms of Cost, Interest, Subsidy and Safety aspects. Kerosene was the least preferred fuel which was evident from the table. Even though the subsidy provided for LPG was far more compared to Biogas or Kerosene, the respondents ranked Biogas ahead of LPG as the higher cost of cylinder was nullifying the effect of subsidy from the psyche of the rural consumer. Even for the cost and interest components, they felt Biogas as the more affordable fuel as the operational cost was significantly low when compared to that of an LPG. Biogas turned out to be the safer fuel as the other two fell short in terms of safety standards. Therefore, barring these few exceptions, LPG was the most preferred fuel in the study area because of its positive attributes.

Table 4. shows the average importance score in terms of the more preferred attributes with respect to the domestic fuels used among the households. Therefore according to the study the households preferred a fuel which has more Durability, Reliability, Sophistication, Less Space needs and Least Ruggedness in cooking. So all these factors clearly pointed towards LPG and the rest of the factors identified had a least say in the purchase decision among the households.

Table 3: Utility (Part worth) Scores

Sl. No.	Factors/Attributes	Utility Estimates/Scores		
		LPG	BIOGAS	KEROSENE
1	**Durability**	**6.667**	0.556	-7.222
2	**Reliability**	**2.667**	0.556	-3.222
3	**Sophistication**	**2.333**	-1.222	-1.111
4	**Space**	**3.000**	-3.778	0.778
5	**Ruggedness**	**2.444**	-1.000	-1.444
6	**Cost**	0.111	**0.667**	-0.778
7	**Interest**	-0.778	**1.556**	-0.778
8	**Subsidy**	0.111	**0.444**	-0.556
9	**Services**	-0.333	-1.333	**1.667**
10	**Distribution**	**1.000**	-0.778	-0.222
11	**Safety**	-0.333	**0.333**	0.22

Table 4: Average Importance Score

Sl. No.	Factors/Attributes	Avg. Score
1	**Durability**	**31.407**
2	**Reliability**	**13.317**
3	**Sophistication**	**8.040**
4	**Space**	**15.327**
5	**Ruggedness**	**8.794**
6	Cost	3.266
7	Interest	5.276
8	Subsidy	2.261
9	Services	6.784
10	Distribution	4.020
11	Safety	1.508

DISCUSSIONS

Biogas, LPG and Kerosene are the three principal clean household fuels in rural India that have substituted biomass for cooking. Two other alternatives, natural gas and electricity, are not commonly used because of lack of general availability for household usage. In the case of natural gas, and in the case of electricity the cost was much higher. Therefore the utility of these three fuels is discussed in a comparative manner.

Comparative Assessment of Domestic Fuels

Costs Incurred by the Consumers

Biogas

Biogas is certainly the most capital intensive solution available among all the technologies. The average cost of a typical 2m³ household system Biogas plant was found to be Rs. 11,498 (with subsidy) and Rs. 21,698 (without subsidy). This excludes the opportunity cost of the land used for building the plant. The household level plant needs lesser additional labour, time and efforts spent towards management of dung or preparation of dung cakes, which can now be diverted towards preparation and handling of slurry and manure. Even though the reported maintenance cost for biogas plants is quite low (Rs. 400 per annum).

LPG

The capital costs associated with LPG included the security deposit for cylinder(s) and pressure regulator, as well as the cost of the gas stove and other administration charges, which together amounted to Rs. 6,800 in the first (installing)

year. The operating costs for LPG based cooking comprises only the cost of fuel. Due to its direct linkage to the international market price and the associated price volatility, it is very difficult to predict variations in the price of LPG.

Kerosene

Kerosene being a liquid fuel doesn't burn as cleanly as gaseous fuels. But nonetheless it is considerably cleaner than the biomass used in traditional stoves. One of kerosene's main advantages is that it is far easier to transport and distribute than gaseous fuels and, unlike LPG, can be purchased in any quantity. Kerosene through public distribution system (PDS) was sold at Rs 14.96 per litre. For households with cash constraints, the ability to buy kerosene in small quantities was attractive. Kerosene stoves, however, typically was more expensive than wood stoves.

Assurance of Fuel Supply

Biogas

Secure and continuous supplies of feed (dung and kitchen waste) and operational availability of the plant are the only critical and necessary conditions to assure fuel supply for a biogas plant. These two conditions dictate that biogas should be promoted and adopted as a solution (i) in areas or households with livestock density and cattle ownership sufficient to meet the required biogas quantities; (ii) and in regions where ambient temperature and climatic conditions would not pose a significant barrier for the plants to function round the year. Apart from the climatic considerations, the operational availability of the plant is dependent on the robustness of the technology and supporting maintenance services. Thus, from the policymakers' perspective on fuel supply assurance, targeted promotion and adoption of biogas should be facilitated, along with the efforts to improve the resilience and management of the technology.

In terms of overall availability of feedstock, the potential for biogas to serve as a cooking fuel is significant. Even though the livestock to human ratio has constantly declined over the years, there are still more than 300 million cattle in the country (Ministry of Agriculture, 2012).

LPG

LPG is already a major cooking fuel. Although the penetration in terms of number of connections has reached close to 175 million (MoPNG, 2014), earlier analysis of NSS data suggested that only 50 per cent of India's cooking energy was derived from LPG (Jain et al., 2015). Even at the current user base, the dependency on import was already as high as 89 percent. The present annual consumption of 16 million tonnes would almost double to 32 million tonnes, if all households were to rely entirely on LPG for their cooking energy needs. This would lead to significant challenges in terms of sourcing LPG, as well as have implications on foreign currency reserves to procure the required crude or the product directly. Apart from the sourcing, the end delivery of the product on a regular basis is also a challenge, which would limit the penetration, regular supply and adoption of LPG, especially in far-flung and poorly accessible locations in the country.

Along with the assurance of fuel supply, a related and important aspect is the 'ease of fuel procurement', which reflects the household's perception of the ease of obtaining fuel. LPG has varying levels of ease, especially in rural India, as it is not delivered at the door-step and households needed to procure it from the distributor.

Kerosene

Kerosene supplied through the PDS is sold at the "fair price" shops which sells subsidized goods. The allocation of subsidized kerosene by the central government varied from state to state and is based on historical patterns rather than

on demand or on consideration of relative poverty levels. The allocation within a state depends on whether the household is in a rural or urban area, and typically on whether or not the household has taken up LPG.

Resilience of the Technology

Just as assurance of fuel supply on a continuous basis is a critical consideration to choose a particular cooking energy solution, the resilience of technology is an equally vital consideration for households before considering a shift of cooking energy technology. At the household level, the resilience of the technology fundamentally means how successfully the particular technology can be used as a primary cooking energy solution, without the need of a backup or alternative. LPG is the most resilient technology on account of the minimal downtime they experience and little maintenance requirements on a periodic basis. Kerosene stoves and Biogas plants fared the worst, indicating that there is still some way to go before end-users view these solutions on par with the LPG. A shift in focus, from mere provision of subsidy to the end-user to a holistic service based delivery model, would be necessary to ensure that this perception of unreliability is mitigated.

Convenience of Cooking

Ability to Accommodate Variety of Utensils and Food Items

The suitability of a cooking energy solution to accommodate a variety of cooking practices, including various cooking utensils and food items, is deemed as the most important criteria, as per the cumulative judgment of the experts. LPG and Biogas have been rated high on this front, whereas Kerosene is lagging behind.

Ease of Control of Flame or Heat Intensity

The ease with which one can control the flame or heat intensity of the cooking energy solution is one of the important criteria that influence the choice of cooking fuels. Both LPG and Biogas are gaseous fuels and use similar (if not identical) stoves for cooking were rated high by the respondents.

Ability for Quick Start-Stop Operation

Ability of a cooking energy technology to be used in quick start and stop operations is a desirable feature, especially when it comes to short cooking durations for certain items such as tea, snacks etc. Unsurprisingly, the two gas-based cooking options (LPG and biogas) were rated as the most suitable for such cooking practices.

Time Taken for Cooking

The time consumed in the cooking process is also considered as an important factor by the experts, which influences the choice of cooking energy solution. Fundamentally, the rate of heat intensity determines the time of cooking. For most cases, the higher the heat intensity, the lower would be the time of cooking. Both LPG and Biogas were considered as ‘fast’ in terms of the time taken by the cooking device to cook a meal. The Kerosene stoves got the lowest rating.

Ease of Management of the Technology

Another important factor is the ease of managing the technology to ensure sustained and reliable performance. This alludes to activities like regular cleaning of cook stoves, daily management of biogas plant (in case of household level plant), etc. LPG was considered the easiest to manage, based on the cumulative opinion of the respondents from the survey. The management of kerosene stove was not deemed as easy. Household-level biogas plants were considered as most

difficult in terms of their management, as compared to other technologies.

CONCLUSIONS

It is quite evident that biogas is a competitive and clean cooking energy option when it comes to economics, cooking convenience and improved indoor air pollution conditions. While its GHG emissions are higher than LPG and PNG, it saves on transportation and production costs and associated emissions. With moderate impacts on the ambient environment, the major area where biogas lags behind is the ‘resilience of technology’ and the challenges associated with plant management. The historic experience with biogas plants in the country has marred the perception of the technology and eroded confidence in the technology amongst rural households. This makes a strong case for innovation in technology design and management, to revive the image of biogas as a sustainable technology as well as to realize the massive untapped potential of this option.

The overall assessment indicates that much needs to be done on the technology improvement front, in terms of emission reduction, enhancing cooking convenience and technology resilience. Technology resilience improvements could also be achieved through better service models. Finally, LPG fares high on cooking convenience, technology resilience and a significantly lower impact on health. However, it has major drawbacks on the economic and supply assurance front. Given the high dependence on imports, the high cost of LPG use is likely to continue. In terms of affordability, it poses a significant burden on the individual and this could translate to a higher fiscal burden on exchequer (on account of the large subsidy provided).

REFERENCES

1. *Debabrata Das., & Srinivasan, R. (2012). Income Levels and Transition of Cooking Fuel Among Rural Poor in India , Energy Science and Technology, 4(2), 85-91.*
2. *Abhishek Jain, Poulami Choudhury & Karthik Ganesan. (2015, February). Clean, Affordable and Sustainable Cooking Energy for India: Possibilities and Realities beyond LPG, CEEW Report, New Delhi.*
3. *Isabel Barfuss et.al. (2012). Household Energy economics in rural Ethiopia: A Cost-Benefit Analysis of Biogas Energy. Renewable Energy, 48(12), 202-209.*
4. *Kabir, H., & Palash, M. S. (2012). Appraisal of Domestic Biogas Plants in Bangladesh. Bangladesh J. Agric. Econs., XXXV, 1&2(2012), 71-89.*
5. *Kanagawa, M., & Nakata, T. (2007). Analysis of the Energy Access Improvement and It Socio Economic Impact in Rural Areas of Developing Countries. Ecological Economics, 62(2), 319-329.*
6. *Heltberg, R., Arndt, T. C., & Sekhar, N. U. (2000). Fuel wood Consumption and Forest Degradation: A Household Model for Domestic Energy Substitution in Rural India. Lend Economics, 76(2), 213-232.*
7. *Kavi Kumar, K.S., & Viswanathan, B. (2007). Changing Structure of Income Indoor Air Pollution Relationship in India. Energy Policy, 35(11), 5496-5504.*
8. *Viswanathan, B., & Kavi, K. (2005). Cooking Fuel Used Pattern in India 1983-2000. Energy Policy, 33(8), 1021-1036.*
9. *Chaurey, A., & Kandpal, T. C. (2009). Solar Lanterns for Domestic Lighting in India: Viability of Central Charging Station Model. Energy Policy, 37(11), 4910-4918.*
10. *The Energy and Research Institute. (2004). TERI Energy Data Directory and Year Book 2003-04. Delhi: TERI Press.*

11. Jain, A., Agrawal, S., & Ganesan, K. (2014, November). Rationalising Subsidies ,Reaching the Underserved: Improving Effectiveness of Domestic LPG Subsidy and Distribution in India, CEEW Report, New Delhi.

12. CSO. (2013). Energy Statistics 2013. Ministry of Statistics and Programme Implementation.

13. Srinivasan, S. (2008). Positive externalities of domestic biogas initiatives: Implications for financing. Renewable and Sustainable Energy Reviews, 12:1476-1484.

14. IDE. (2011). Annual biogas users survey 2010. Report submitted to Infrastructure development Company Limited (IDCOL), Dhaka.

15. Purohit P., & Kandpal, T. C. (2007). Techno-economics of biogas-based water pumping in India: An attempt to internalize CO2 emissions mitigation and other economic benefits. Renewable and Sustainable Energy Reviews, 11:1208–1226.

16. Biswas, W. K. & Lucas, D. J. N. (1997). Economic viability of biogas technology in a Bangladesh Village. Energy, 22, 763-770.

17. Singh, K. J. & Sooch, S. (2004). Comparative study of economics of different models of family size biogas plants for state of Punjab, India. Energy Conversion and Management, 45: 1329–1341.

18. Ministry of Agriculture. (2012). 19th Livestock Census-2012.

19. MoPNG. (2014a). Government of India, Ministry of Petroleum and Natural gas.